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اللجنة الدولية الحكومية لعلم المحيطات

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FEATURES

Tsunami and Other Waves

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"For more than 200 years, the small group of volcanic islands in the Sunda Strait, between Sumatra and Java, has been dormant, and by the 1880s the local inhabitants were confident that the volcanoes were dead.

In the spring of 1883 this confidence was broken by a sudden explosion that could be heard 100 miles away in Batavia -- now the Indonesian capital of Djakarta. It was the first indication that Krakatoa, the sleeping guardian of the straits, was awakening. During the next few months there was continued activity from the islands, and on August 26 another huge eruption took place. At the same time, a new phenomenon appeared: a large wave, created by the underwater activity of the volcanoes, bore down on the neighboring coasts, swamping villages and causing death and destruction. The next morning Krakatoa was torn apart by a series of colossal detonations, the third of which may have been the biggest explosion in the earth's history and was heard 3,000 miles away on the other side of the Indian Ocean. Three more giant waves thundered onto shore, completely destroying villages and settlements all along the coasts of Java, Sumatra,

The area behind the Hilo (Hawaii) Theater was reduced to rubble after tsunami waves struck in May 1960.

Borneo, and other islands. At Merak, a town situated at the end of a bay that narrowed rapidly, the water was forced higher as it advanced and the wave grew. When it hit the town, completely destroying it, the wave was more than 135 feet high. By the end of the day more than 37,000 people had been killed in the East Indies.

The giant wave that resulted from the eruption of Krakatoa was probably the most destructive in history. At the time, it was generally referred to as a tidal wave, but it had nothing to do with tides. Today, waves of the same type are more generally referred to as tsunami, the Japanese word for "harbor wave."

Just thirteen years after the Krakatoa eruption, the coast of Honshu -- the largest of the Japanese islands -- was struck by a series of waves that were almost as deadly. On June 26, 1896, a mild earth tremor was felt, and almost immediately afterwards the sea began to withdraw from the coast. Then came a far-off hissing that came steadily closer, grew louder and louder, and turned into a roar as a wave estimated at 110 feet high towered above the coast and smashed down. When it was all over, more than 27,000 people were dead.

Tsunami are probably the most destructive of all waves, not only because of their size, but because they are so difficult to detect or predict. Unlike other oceanic disturbances, they are not a product of weather, but of seismic activity. The most frequent cause is a fault produced by tension in the earth's crust: a large mass of rock, subject to enormous stress, finally drops or rises. If this takes place beneath the sea, the water above will either drop or be forced upwards. In either case, the result will be a giant wave, or waves, that race off from the center of activity at an incredible speed. It has been estimated that some of these waves can travel at more than 500 miles per hour, and cover enormous distances.

Tsunami can also be caused by underwater landslides, themselves generally caused by earthquake activity, or, more rarely, by volcanic eruptions such as Krakatoa, and the eruption of the Greek island of Santorini around 1500-1400 B.C. that probably destroyed the Minoan civilization of Crete and possibly explains the disappearance of the mysterious Atlantis.

In the open sea, tsunami are almost undetectable. When a tsunami struck Hilo, Hawaii, in 1946, the crew of a freighter a mile offshore watched the waves crashing over the tops of buildings in Hilo, without being aware that anything was passing beneath the keel of their ship. The successive waves of a tsunami in deep water are so far apart -- perhaps 100 miles and fifteen minutes -- and so low -- maybe only a couple of feet -- and so extremely gradual in slope that they are literally undetectable. It is when they reach shoal areas that they are transformed into terrifying monsters as tall as 100 feet.

A tsunami wave is a shallow-water wave, even when passing through the deepest part of the oceans. A shallow-water wave is one where the wave length (the distance between crests) is much greater than the water depth. So, even though a tsunami may be crossing an ocean basin three miles deep, the waves are still classified as shallow-water waves because their length is so great -- often more than a hundred miles.

Another characteristic of a shallow-water wave is that its speed is proportional to the square root of the depth of the water: a tsunami wave in water 18,000 feet deep travels about 500 miles an hour; in water 900 feet deep, 115 miles an hour; and in 60 feet, 30 miles an hour. When a tsunami approaches shore, shoaling causes its waves to telescope by increasingly restricting their forward motion as the water becomes shallower. Also, the waves grow taller and the distance between them shrinks. In this fashion, a 2-foot wave traveling 500 miles an hour in deep water becomes a 100-foot killer traveling 30 miles an hour when it approaches shore. Throughout, however, the time interval between crests tends to remain large; this is one of the most significant characteristics of a tsunami at any stage.

The effect of the same tsunami wave may be vastly different from one point on shore to another. Local topography is usually responsible: a bay or an estuary has a funneling effect, which accentuates the height of the wave; an offshore shoal or sandbar diminishes it. This is why in the one area the wave may be fifty feet tall, while at a point a few miles away it might be only five feet in height.

It is the fundamental relationship between the speed of a tsunami wave and the water depth which has permitted scientists to produce a workable warning system. Accurate tsunami travel-time charts have been prepared for populated points throughout the Pacific basin and its borders, allowing monitoring of the progress of the tsunami as it travels across the Pacific. A substantial period of watchful waiting before issuing an all clear is advised for good reason: the long gap between successive tsunami waves has lulled people into returning too soon to evacuated areas, only to be trapped and drowned by a successor wave, perhaps the biggest of all.

Although predictions of arrival times for first waves of tsunami are satisfyingly accurate, predictions of tsunami magnitude are not. In fact, scientists say, because of the bewildering number of local effects that can cause variations in tsunami, it is not now possible even to tell if a known tsunami will have any significant effect at all on shore. Consequently, there is an inescapable amount of overwarning.

Another puzzle involving tsunami is that it is usually not the first wave that causes the most damage, but a later one. Sometimes the biggest tsunami wave will be what is known as a bore, which occurs when one wave overtakes a preceding wave, producing a steep-faced wall of water. One of the most destructive of these was associated with the Chilean tsunami of May, 1960, which inflicted major damage on Hilo, Hawaii. It was triggered by an earthquake which shook Chile on May 22; the destructive waves reached Hilo just after midnight on May 23. The tsunami had traveled the 6,600 miles in just under fifteen hours, at an average speed of 442 miles an hour. Because of timely warnings, the death toll of sixty-one was much less than for previous, comparable tsunami.

For ships on the open seas, tsunami are normally quite harmless. Far more deadly are conventional, wind-produced waves which, in the right conditions, can reach dimensions almost as colossal as the most powerful tsunami.

Waves normally originate through the effect of wind upon the sea. The surface ripples undulate, and as the wind grows stronger the sea surface becomes more agitated. Eventually jagged, white-capped peaks will be formed. Really big waves, however, require more time and distance than such local storms can provide. Propelled by the wind, the storm waves eventually change their shape, becoming more rounded and regular. If the wind continues to blow strongly, this swell will continue to grow in size as it moves across the ocean's surface at up to thirty-five miles per hour, with a period of roughly ten seconds between each crest. These waves can travel thousands of miles, and the further and harder the wind drives them, the bigger and more dangerous they can become.

Normally these waves do not reach more than twenty-five feet in height, but there are exceptions. Sometimes wave trains that have originated in different centers will combine, and within any train there will always be some waves that are bigger than the rest. It has been calculated that one wave in 23 will be twice the average height, one in 1,715 will be three times the average, and one in 300,000 will be four times higher than the average.

Since wave height depends upon the strength of the wind, depth of water, and the distance traveled, it follows that the greatest waves are found in those oceans which are deepest and provide the greatest fetch or distance uninterrupted by land. The Pacific Ocean is one such area. The North Atlantic generally produces even bigger waves, and large wind-waves are also found in the southern oceans -- the Roaring Forties of the old sailing ship days.

Refinement of the tsunami warning system through faster communications between far-flung seismological observatories and tide stations, and coastal dwellers, is perhaps the limit to man's defense against the awesome power of tsunami. However, research is under way to harness the energy generated by waves for the benefit of man.

One system involves using the vertical movements of waves to drive pumps and other installations. A float in the sea would be balanced by a counterweight on land, and in between there would be a double-reciprocating pump activated by a pulley. A series of such pumps could supply a reservoir which could be used to generate hydroelectric power.

Another research project envisages the use of a number of "rocking duck" vanes which would extract the energy of the waves as they pass by. Linked in groups, the vanes would send jets of water through turbines which would convert the energy into electricity. Another system involves a chain of floats, linked by pistons which would rock back and forth as the waves moved. The pistons could be used to pump water into reservoirs on shore, which could then be used for the creation of hydro-electricity.

Such projects are, of course, still in their infancy. It will be many years before the vast energy of the waves can be utilized for man's benefit, and in the meantime, the most he can do is try to lessen the harm that waves can do.

And that is not an easy task. In 1958, an earthquake in Alaska sent ninety million tons of rock crashing 3,000 feet into Lituya Bay in a remote coastal area of Alaska. A huge wave was sent across the bay at 100 miles per hour, and rose above the land on the other side to a claimed maximum height of 1,740 feet. Against a natural force of that scale, there can be no real defense."

Tsunami Data Activities of World Data Center A

During the past several years World Data Center A (WDC-A) has increased its efforts in developing a tsunami data base to service requirements for tsunami research and tsunami risk. Much of this work is being done in cooperation with the International Tsunami Information Center and participants in the Tsunami Warning System. The purpose of this article is to describe the present role of WDC-A, its tsunami activities, and planned projects.

The World Data Center system was established at the outset of the International Geophysical Year (1957) by the International Council of Scientific Unions (ICSU) for the purpose of exchanging scientific data among participating countries. The World Data Center idea proved useful and in many cases the role was expanded after the IGY. The World Data Centers are now involved in the archiving and distribution of data for disciplines in solid earth geophysics, glaciology, oceanography, rockets and satellites, meteorology, and solar-terrestrial physics. The United States and the USSR operate World Data Center-A and B, respectively, for each of the disciplines or sub disciplines. Other countries operate World Data Centers for one or more disciplines or sub disciplines.

The guidelines for data exchange and the roles of the WDC's are established by relevant associations and unions of ISCU. Guidelines are periodically rewritten and published a document titled "Consolidated Guide to the International Exchange of Data Through the World Data Centres."

The guidelines relating to tsunamis are prepared by the joint International Association of Seismology and Physics of the Earth's Interior/International Association of Physical Sciences of the Ocean (IASPEI/IAPSO) Committee on Tsunamis. The World Data Center-A activities in tsunamis are performed as part of the World Data Center for Solid Earth Geophysics which is operated by the Environmental Data and Information Service of the National Oceanic and Atmospheric Administration.

The principal objective of the WDC-A Tsunami program is the compilation of data sets as a service for those studying tsunamis. This includes (1) a project for microfilming all available tide gage mareograms with tsunami activity; (2) a photo file of tsunamis and resulting effects; and (3) computer files containing tsunami wave data and related seismic data.

The microfilming project for all available tide gage mareograms now is focused on the historical records of the National Ocean Survey/NOAA and its predecessor agency, the Coast and Geodetic Survey. Records from this source exist from 1854 to the present time. Those events listed in the NGSDC "Earthquake Data File" and the "Preliminary Catalog of Tsunamis Occurring in the Pacific Ocean" by Iida, Cox, and Pararas-Carayannis have been selected for copying and will be available in microfiche and roll film formats. At this writing 700 records for 30 tsunamis for 1962 to 1975 are available.

Since 1971 the Guide has called for the collection of all mareograms showing preceptible tsunami activity from participating stations. WDC-A will try to complete this collection for as many stations and events as possible.

Future efforts for this file include obtaining historic mareographic data for tsunamis from member states of the International Hydrographic Organization and the participants in the Tsunami Warning System.

The photographic file now being assembled has many contributors including: International Tsunami Information Center, U.S. Army Corps of Engineers, U.S. Navy, and the Japan Meteorological Agency. The file is composed of more than 600 photographs, each with a caption giving photograph and event dates, photograph orientation and description. WDC-A plans to expand the photograph collection effort in conjunction with the mareogram collection.

An illustrated catalog of these photographs will be published shortly and WDC-A would appreciate receiving any other tsunami effect photographs from any source.

Computer files are being assembled that contain two types of information: (1) seismological data about the generating events such as magnitude, focal depth, and location of epicenter; (2) tsunami wave data, such as travel times, run-up heights, and first motion. Searches and plots of the data will be available to researchers according to their specifications.

Contributors of mareogram photos can receive a like amount in exchange for data contributed free-of-charge. Data is available to others at the cost of copying.

Arrangements can be made for special plots, digitization of mareograms and other special services. The Data Center is open to visitors for use of the data and facilities by arrangement. Support for longer term guest workers is possible.

If the present and future efforts of WDC-A are to be beneficial to those studying tsunamis, and ultimately reduce the destructive effects of this natural hazard, there needs to be a continuing cooperative data and idea exchange between World Data Centers and the scientists involved in the study of tsunamis. Data sets available from WDC-A will be announced in articles appearing in the ITIC Newsletter.

Further information about tsunami data and activities in World Data Center-A may be obtained from:

World Data Center-A for Solid Earth Geophysics
Environmental Data and Information Service
National Oceanic and Atmospheric Administration
Boulder, Colorado 80303

(303) 499-1000 Ext. 6334

NEWS EVENTS

The National Science Foundation Sponsors a Tsunami Research Workshop on May 7-9, 1979 at Trabuco Canyon, California

The workshop consisted of a series of group discussions among foreign and domestic experts in a variety of tsunami-related fields, seeking to channel research efforts toward the understanding and prediction of tsunamis. Topics that were discussed included earthquake ground motion, effects of wave forces on structures, and behavior of tsunamis. Proceedings will be published.

Information is available from:

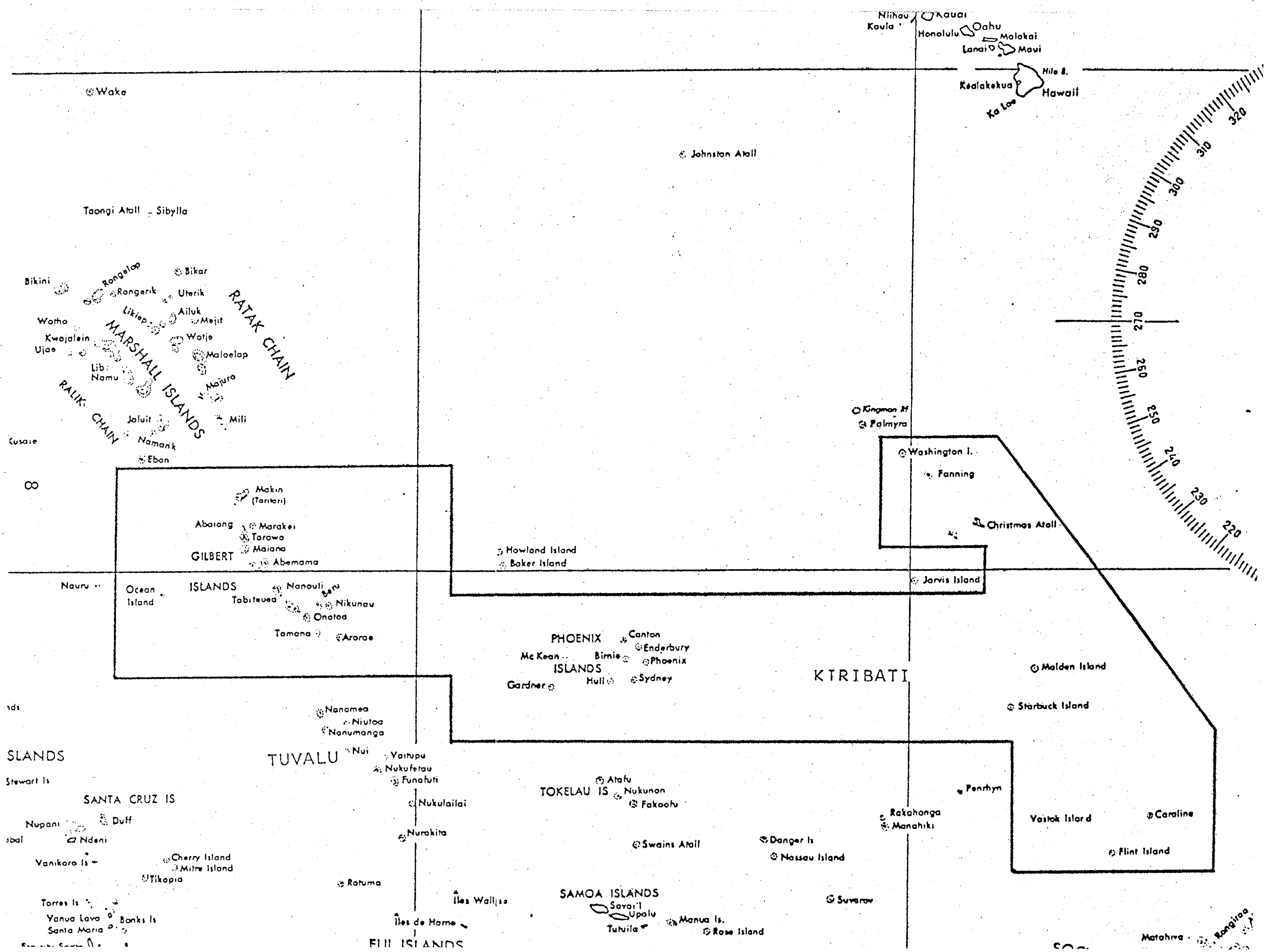
Dr. Li-San Hwang, Tetra Tech, Inc.
630 No. Rosemead Blvd.
Pasadena, California 91107

(213) 449-6400

Republic of Kiribati

The Phoenix, Line, and Gilbert Islands will form the Republic of Kiribati on July 12, 1979. With its capital on Tarawa in the Gilbert Islands, the new nation will stretch 2700 miles eastward to the Line Islands, where Christmas Island, 52 square miles in area, will constitute 55 per cent of the dry land acreage. However, the sea area to which it may lay claim under the 200 mile limit, would be two million square miles. Population of Kiribati will be about 60,000, mostly Micronesian. A map of the Kiribati area is on the page following.

Christmas Island was named by Captain James Cook. On December 24, 1977, he sighted an uninhabited atoll where he remained to observe an eclipse of the sun on December 30. As Christmas Day was spent there, Cook named the island Christmas Island. Continuing his search for a passage between the Pacific and the Atlantic, Cook continued on a northerly course and on January 18, 1778, sighted the islands that were to become known as the Hawaiian Islands.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Johnston Atoll
Taongi Atoll
Sibylla
Bikini
Rongelap
Rongerik
Bikar
Uterik
Likiep
Ailuk
Mejit
RATAK CHAIN
Wotho
Kwajalein
Ujae
MARSHALL ISLANDS
Wotje
Maloelap
Lib
Namu
Majuro
RALIK CHAIN
Jaluit
Mili
Namarik
Kusaie
Ebon
Kingman Rf
Palmyra
Washington I.
Fanning
Christmas Atoll
Makin
(Taritari)
Abaiang
Marakei
Tarawa
Maiana
GILBERT
Abemama
Howland Island
Baker Island
Jarvis Island
Nauru
Ocean
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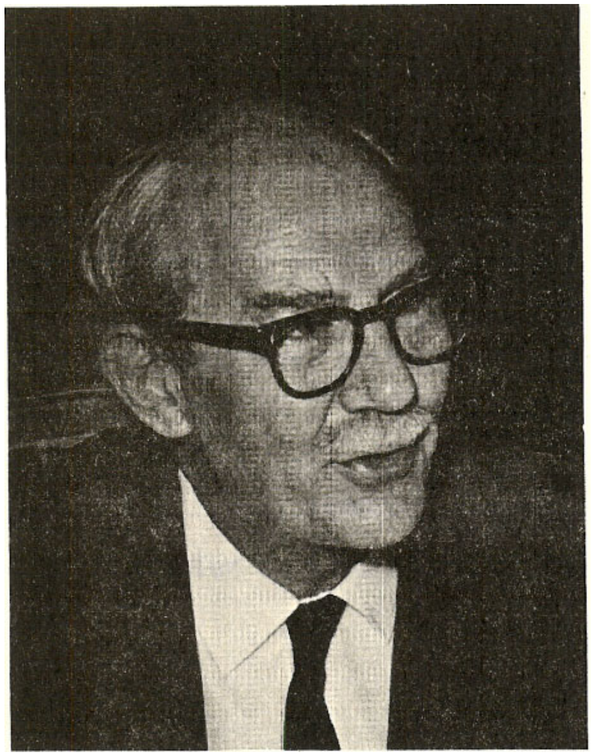
Tabiteuea
Nikunau
Onotoa
Tamana
Arorae
PHOENIX
Canton
Enderbury
Mc Kean
Birnie
Phoenix
ISLANDS
Gardner
Hull
Sydney
KIRIBATI
Malden Island
Starbuck Island
Nanomea
Niutao
Nanumanga
SLANDS
TUVALU
Nui
Vaitupu
Nukufetau
Funafuti
Stewart Is
SANTA CRUZ IS
TOKELAU IS
Atafu
Nukunon
Fakaofu
Penrhyn
Duff
Nupani
Ndeni
Nukulailai
Rakahanga
Manahiki
Vostok Island
Caroline
Nurakita
Swains Atoll
Danger Is
Nassau Island
Vanikoro Is
Cherry Island
Mitre Island
Tikopia
Flint Island
Rotuma
Iles Wallis
SAMOA ISLANDS
Savai'i
Upolu
Suvarov
Torres Is
Vanua Lava
Santa Maria
Banks Is
Iles de Horne
Tutuila
Manua Is.
Rose Island
FIJI ISLANDS
Matahiva
Rangiroa



Dr. George Woollard Dies

Dr. George Woollard, internationally acclaimed geophysicist and director of the Hawaii Institute of Geophysics (HIG) at the University of Hawaii for a number of years, died at age 70, on April 8, 1979.

During his directorship of Hawaii Institute of Geophysics, Dr. Woollard helped make the University of Hawaii one of the nation's top recipients of grants and contracts for specialized research in the marine sciences. The HIG has been one of the most successful of the University's attempts at excellence in fields of special relevance to Hawaii. At the institute, where he was often seen nights and weekends, Dr. Woollard was known as one who led by an example of hard work. The international scientific community, laments the passing of Dr. George Woollard.

UNESCO - IOC - ITSU

11th Session of Executive Council

Inaugurated on 26 February by the President of Mexico, Sr. Jose Lopez Portillo, the eleventh session of the IOC Executive Council met for six days in the Centro Interamericano de Estudios de Seguridad Social in Mexico City. The Director-General of Unesco was represented by Dr. Abdul-Razzak Kaddoura, Assistant Director-General for Science.

The main item before the council at this session was consideration of a report from the Working Group on the Future Role and Functions of the Commission. Since its establishment by the tenth session of the IOC Assembly, this group has met twice to define the major issues likely to confront the Commission during the coming decades (see IMS-18).

A large number of studies have emerged from the deliberations of the working group on topics such as the possible need to revise the IOC statutes, additional sources for funding, future directions for the IOC's marine science programme, and the Commission's work methods.

Other important matters which came up for discussion were: co-participation and co-operation by all member states in the oceanographic aspects of the Global Weather Experiment; approval of the recommendations and research proposals made by the newly-formed working group for the Western Pacific; and an expression of appreciation to the government of Venezuela for its first contribution of $50,000 to the IOC Trust Fund in support of activities in the Caribbean and adjacent regions.

11th Session of the Assembly of the Intergovernmental Oceanographic Commission (IOC) and 12th Session of the IOC Executive Council

The Eleventh Session of the Assembly of the Intergovernmental Oceanographic Commission will be held in UNESCO House, Paris from Monday, 15 October to Saturday, 3 November 1979, as follows:

Preparatory Meetings	15-20 October 1979
Plenary Sessions	25 October - 3 November 1979

The Twelfth Session of the IOC Executive Council will be held on 22-24 October 1979. For further information, write:

Secretary
Intergovernmental Oceanographic Commission
UNESCO
7 Place de Fontenoy
75700 Paris, France

INTERNATIONAL TSUNAMI INFORMATION CENTER - HONOLULU

Norman Ridgway's Term of Office Expires

Mr. Norman Ridgway returned home to New Zealand at the end of June of this year after serving for the last one and a half year as Associate Director of ITIC. Mr. Ridgway is returning back to his position as Senior Oceanographer with the New Zealand Oceanographic Institute at Wellington.

During his term of office at ITIC, Mr. Ridgway contributed greatly to the administration of ITIC and initiated a number of new projects. His support over this period was inspirational and helped in building a good program for ITIC and a good service for the Pacific Community of Nations interested in the Tsunami Warning System, and tsunamis in general.

Review of the Response of Tide Stations in the Tsunami Warning System
By: George Pararas-Carayannis, Director, ITIC
Eddie Bernard, Director, Pacific Tsunami Warning Center

Introduction

The Pacific Tsunami Warning Center (PTWC) is responsible for the detection of tsunamis resulting from major earthquakes and the dissemination of tsunami information to cooperating agencies in the Pacific Basin. In order to fulfill this responsibility, timely tide data is required from the cooperating tide stations.

At the Sixth Session of the International Coordination Group for the Tsunami Warning System in the Pacific in Manila, Philippines, 20-25 February 1978, and in reviewing proposals for further technical improvements for the System, the Group was of the opinion that the goal of the Tsunami Warning System (TWS) should be to verify the existence of a tsunami within one hour after the time of generation. ITIC and PTWC were given the responsibility of preparing a report assessing the present Tsunami Warning System and of defining a system of stations needed to achieve this goal.

In response to the ITSU directive, a detailed and critical analysis was undertaken of the response capability of present stations in the TWS based on historical tsunami data and on assessment of communication delays during actual tsunami investigations.

Response Analysis

A review was made of PTWC earthquake logs from 1969 through 1978. During this period, 33 of 52 tide stations were queried by PTWC during actual tsunami investigations. The 34 stations were interrogated a total of 195 times with a satisfactory response 114 times (59%) and an unsatisfactory response 71 times (36%). Communication or instrumental outages occurred 10 times (5%). Table 1 is a list giving the responses of individual stations and the time percentages that these stations responded within an hour.

Stations with 90% or greater reliability along with stations that have shown reliable communication in the past two years are represented by asterisks. These stations, in our opinion, would respond appropriately during a tsunami investigation. From this table it is seen that 57% of the existing tide stations in the Tsunami Warning System can presently meet this criterion of responding within an hour after a query is initiated by PTWC. Adding the time delays of PTWC in evaluating the earthquake parameters and in interrogating the tide station, the response efficiency, even of the better stations is furthermore reduced, making the one hour objective unattainable most of the time for 43% of the tide stations. The weakness of the response capability of TWS is illustrated in Figure 1. In this figure, the one hour travel time curves have been plotted around each of the tide stations in the TWS that historically have responded within a reasonable time interval, or have present communications to do so. The weakness of the present Tsunami Warning System is obvious and unacceptable.

Table 1. Tsunami Tide Station Responses from 1969 through 1978

Station	Total Number of Queries	Number of Satisfactory Queries	Satisfactory Response % Time
Acajutla, El Salvador	8	6	75%
*Adak (Sweeper Cove), Alaska	2	2	100%
Antofagasta, Chile	4	0	0%
Apia, Western Samoa	8	5	63%
Arica, Chile	5	1	20%
Balboa, Canal Zone	7	3	43%
Baltra Island, Galapagos Islands, Ecuador	4	0	0%
*Crescent City, California	No Query		
Easter Island	2	0	0%
*Fort Point, San Francisco, California	No Query		
*Guam, Mariana Islands	14	11	79%
*Hachinohe, Japan	7	6	86%
*Hilo, Hawaii	No Query		
*Johnston Island, Pacific Ocean	No Query		
*Kodiak, Alaska	No Query		
*Kushiro, Japan	No Query		
*Kwajalein Atoll	9	8	89%
*Langara Island, Canada	No Query		
La Punta, Callao, Peru	7	4	57%
Legaspi, Luzon, Philippine Islands	9	1	11%
Malakal Island, Palau Islands	12	7	58%
Manzanillo, Colima, Mexico	3	1	33%
*Marsden Point, New Zealand	4	4	100%
*Midway Island, Pacific Ocean	No Query		
Minamitorishima (Marcus Island)	6	1	17%
Moen Island, Truk Islands	No Query		
*Nawiliwili, Kauai, Hawaii	No Query		
Noumea, New Caledonia	11	4	36%
*Pago Pago, Tutuila, American Samoa	6	6	100%
*Papeete, Tahiti	1	0	0%
Puerto Montt, Chile	1	0	0%
Puerto Williams, Chile	No Query		
Punta Arenas, Chile	No Query		
Rikitea, Mangareva Island, Gambier Isles, French Polynesia	No Query		
*San Diego, California	No Query		

Table 1. Tsunami Tide Station Responses from 1969 through 1978 (cont.)

Station	Total Number of Queries	Number of Satisfactory Queries	Satisfactory Response % Time
*Sand Point, Alaska	No Query		
*San Pedro, California	No Query		
*Seward, Alaska	No Query		
*Shemya, Alaska	No Query		
*Shimizu (Tosa), Japan	No Query		
*Sitka, Alaska	No Query		
Socorro Island, Colima, Mexico	1	0	0%
*Suva, Fiji	13	10	77%
Talcahuano, Chile	1	0	0%
*Tofino, British Columbia, Canada	1	1	100%
*Unalaska, Alaska	No Query		
*Valparaiso, Chile	2	1	50%
*Wake Island, Pacific Ocean	No Query		
*White Beach, Okinawa	9	9	100%
*Yakutat, Alaska	No Query		
Yap, West Caroline Islands	9	7	78%

* Stations that by historical reaction or by present communication systems indicate they can respond to tsunami query within one hour.

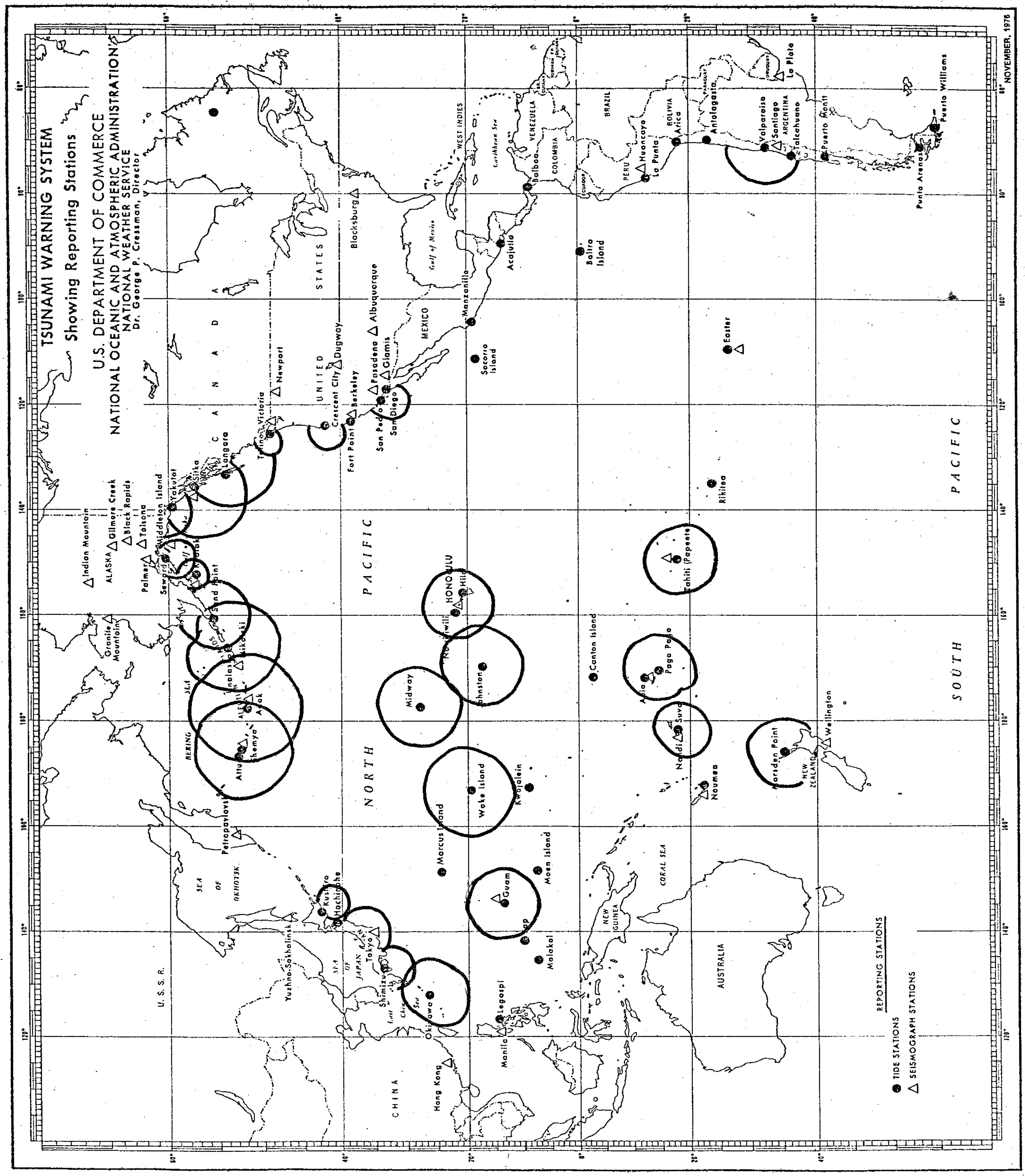


Figure 1. One hour tsunami travel time front for stations responding satisfactorily

Conclusions and Recommendations

The geographical distribution of tide gauge stations in the present TWS suggests a reasonable coverage of the Pacific, but in actuality, response analysis indicates that this is not the case. 57% of the officially designated tsunami tide stations respond acceptably to queries initiated by PTWC. A serious weakness exists in the present TWS. Large, virtually uncovered, areas exist in the Pacific where present means of communication do not allow timely response for tsunami data needed in assessing tsunami generation. The problem is more acute to regions of Mexico, Central and South America, for the Southwest Pacific, for the Philippine Islands, for the northern part of the Kuril Islands and for Kamchatka.

Reasonable response capability can be achieved by automating all of the existing tsunami stations and using geosynchronous satellite communications. The one hour response criterion can be met only by automating, not only existing stations, but some additional stations. The use of geosynchronous satellites and automated tide platforms are necessary for the efficient operation of the TWS.

Determination of a tsunami within one hour after its generation is the desirable goal. With the existing TWS stations -- if equipped with remote sensors and satellite communications -- it may be possible to achieve a minimum two hour response at least in the most active tsunamigenic areas where present weaknesses exist. Efforts should be made to equip these stations first, then try to meet the one-hour response requirement by establishing additional automated tidal stations. In view of that objective, it is recommended that the following of the existing tsunami tidal stations be equipped with automatic devices that will allow interrogation by PTWC or automatic event detection via geosynchronous satellite communications. These stations are listed in order of priority:

1. Baltra I. (or other Galapagos Islands)
2. Acajutla
3. Socorro I.
4. Arica
5. Easter I.
6. Valparaiso
7. La Punta
8. Paramushir, Iturup, Kunashir Islands
9. Puerto Montt
10. Antofagasta
11. Talcahuano
12. Legaspi
13. Suva
14. Honiara
15. Malakal
16. Papeete

EDITORIALS AND LETTERS

Commemorative Service Held for Missing University of Hawaii Scientists

Extensive air and sea searches have failed to discover any clues regarding the fate of the motor vessel "Holo Holo," which went missing on December 9, 1978 during a research cruise off the west coast of the island of Hawaii.

On January 8, 1979 a commemorative service was held at the McCoy Pavilion, Ala Moana Beach Park, Honolulu, for the three University of Hawaii scientists who were on board the vessel -- Michael Allen, Robert Harvey and Gary Niemeyer.

A biographical sketch, written by Bob's wife (Youngsook Kim Harvey), which appeared in the program of the service, is reprinted here. We know that all our readers will share our deep distress and sadness at this terrible tragedy.

"Robert Richard Harvey was born in Emsworth, England, on April 23, 1939, to Captain John Dwight Harvey, Royal Navy, Fleet Air-Arm, and Joyce Elizabeth Marett Harvey. Bob, the youngest of four, has two sisters and a brother. The eldest, Ann Elizabeth Day, a painter and a poetess, lives in Salt Lake City, Utah, where she works as the Curator of Educational Services, Utah Museum of Fine Arts. His brother, John Harvey, a linguist specializing in Korean, is a graduate of Deerfield Academy and Harvard. He is on his way to Korea to start a program in linguistics at Ajou Institute of Technology in Suwon, Korea. Gillian Mary McLoughlin, like her sister Ann, graduated from Mt. Holyoke. Gill did graduate work at Courtauld Institute, London University, and worked as an art historian at the Metropolitan Museum of Art in New York before her marriage to John McLoughlin. Bob has two nephews and a niece from Ann, and two nieces and a nephew from Gill. His mother, now married to Walter Prince, lives in Duxbury, Massachusetts.

Bob graduated from Deerfield Academy, Old Deerfield, Massachusetts, in 1954, and from Cornell University, Ithaca, New York, in 1962, from a degree in Engineering Physics. He worked at Lawrence Radiation Laboratory in Livermore, California, and took graduate courses in Nuclear Physics at Berkeley from 1962 to 1965. He came to Hawaii in 1965 to start his graduate studies in Physical Oceanography at the University of Hawaii and received his Ph.D. in 1972. He has been employed by the University since 1965, first with Joint Tsunami Research Effort and now with Joint Institute of Marine and Atmospheric Research. He is currently involved in NORPAX, DUMAND, and preparing for a third joint effort with scientists from the USSR.

Bob and I were married in 1967, and my two children, Andrew and Sarah Weaver, adopted him as their father and friend, giving him a ready-made family."

NATIONAL AND AREA REPORTS

TSUNAMI DATA RECEIVED FROM USSR AT PACIFIC TSUNAMI WARNING CENTER (PTWC) DURING 1978

Event Number	Magnitude	Date/Time	Region	Sent	Received	Data Received
1	6.3	14 Jan 0325Z	Honshu	0415Z	0503Z	P - 140327Z Mag 7 Tsunami expected 32N/140E
2	6.7	9 Feb 2135Z	Kermadecs	2320Z	2329Z	P - 21488 Mag 7
4	7.2	23 Mar 0315Z	Kuriles		0403Z	P - 230316Z Mag 7 Tsunami expected 44N/149E
					0438Z	Paramishir 0546Z 7m Iturup 0345Z 3m Kunashir 0431Z 2m Shikotan 0348Z 3m
					0534Z	Yuzno Kurilsk 25 cm recession
					0610Z	Tsunami warning cancelled
6	7.3	24 Mar 1947Z	Kuriles	2002Z	2040Z	P - 241949 Mag 7.6
				2010Z	2052Z	Iturup 2023Z 4m Kunashir 2105Z 2.3m Shikotan 2912Z 3.3m
				2305Z	2345Z	Euznokurlisk 2035Z 20 cm rise
				2307Z	2345Z	Warning cancellation at 2250Z
7	7.7	12 Jun 0814Z	N.E. of Honshu	0850Z	0900Z	P - 081428Z Mag 7.2
					0923Z	Kunashir 1007Z 14m Shikotan 0917Z 22m
					0943Z	Tsunami expected 39N/142E
10	7.1	23 Jul 1442Z	Philippines	1525Z	1548Z	P - 231448 Mag 7
13	6.8	4 Nov 2230Z	Samoa Is.		0023Z	P - 233940 Mag 7
14	7.5	5 Nov 2202Z	Solomon Is.		0036Z	P - 221216Z Mag 7.2
15	7.5	29 Nov 1952Z	Mexico	2110Z	2130Z	P - 200626 Mag 7

TSUNAMI DATA SUPPLIED TO USSR BY
PACIFIC TSUNAMI WARNING CENTER (PTWC) DURING 1978

Event Number	Magnitude	Date/Time	Region	Time Message Sent	Data
1	6.3	14 Jan 0325Z	Honshu	0533Z	Press Release
2	6.7	9 Feb 2135Z	Kermadec	2232Z	Press Release
3	6.5	22 Mar 0050Z	Kuriles	0134Z	Press Release
4	7.2	23 Mar 0315Z	Kuriles	0651Z	Press Release
5	6.5	23 Mar 1912Z	Kuriles	2000Z	Press Release
6	7.3	24 Mar 1947Z	Kuriles	2023Z 2212Z	Lat/Long Message Press Release
7	7.7	12 Jun 0814Z	N.E. of Honshu	0938Z 1003Z	Tsunami Watch Watch Cancellation
8	6.6	14 Jun 1232Z	Philippines	1355Z	Press Release
9	7.4	17 Jun 1511Z	Samoa	1707Z	Press Release
10	7.2	23 Jul 1442Z	Philippines	1635Z	Press Release
11	6.6	23 Aug 0038Z	Costa Rica	0156Z	Press Release
12	7.7	16 Sep 1536Z	Iran	1701Z	Press Release
13	6.8	4 Nov 2230Z	Santa Cruz	2331Z	Press Release
14	7.5	5 Nov 2202Z	Solomon Is.	2311Z 0023Z 0149Z	Tsunami Watch Watch Supplement Watch Cancellation
15	7.5	29 Nov 1952Z	Mexico	2100Z 2242Z 0012Z	Tsunami Watch Watch Supplement Watch Cancellation

Proposed Tsunami Magnitude Scale

In a paper to appear in a forthcoming issue of the Journal of Marine Geodesy, Drs. T. S. Murty and H. G. Loomis propose that the tsunami community adopt a tsunami magnitude scale based on the logarithm of the total energy. They are proposing that tsunami magnitude M be given by

$$M = 2(\log E - 19)$$

where the energy E is expressed in ergs.

With this definition, the range of tsunami magitudes runs from 0 to 10 (or more) for tsunamis ranging from the smallest to the largest known so far.

The authors were working on the problem of correlating seismic moment and tsunami magnitude when it became apparent that the usual measures of tsunami magnitude based on wave height were not sufficiently well defined. Tsunami wave heights are very much determined by distance from the source region, directivity of the tsunami, shoaling, and numerous other variables. Wave height, or the destructive capacity of a tsunami is a measure closer akin to seismic intensity as was noted by Soloviev in 1970. (Tsunamis in the Pacific, W.M. Adams, ed.)

The authors decided that energy was the best measure of the size of a tsunami and that measured wave heights from different places could be used for preliminary estimates of energy, but that the final determination of tsunami magnitude would come when all of the known information about the earthquake and tsunami could be put together.

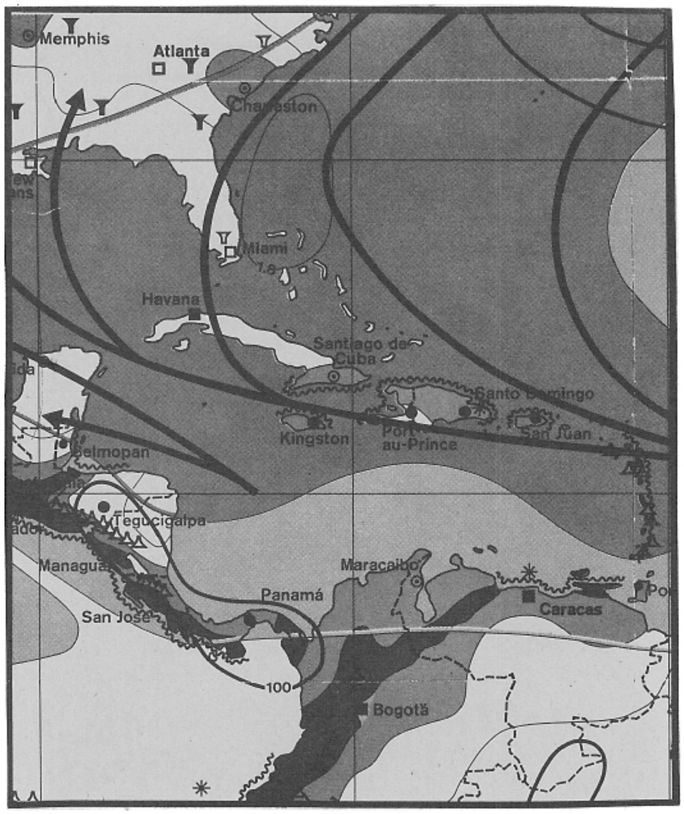
It seems likely that with progress in measuring waves in the deep ocean and with progress in seismology in defining source areas and motions, it will become possible to make better estimates of the total tsunami energy at the time of generation.

A partial chronological list of major tsunamis during the period 1893-1973 is shown below in Table 1. The values in the final column should be treated as tentative until better estimates are available.

Table 1. Preliminary Estimates of Tsunami Magnitude

Date	Location of Earthquake	Murty/Loomis Tsunami Mag
Jun 15, 1896	Sanriku	8.4
Sep 7, 1918	Urup	9.1
Nov 11, 1923	Kanto	9.1
Mar 2, 1933	Sanriku	8.4
Apr 1, 1946	Aleutian Is.	9.8
Nov 4, 1952	Kamchatka	8.3
Mar 9, 1957	Aleutian Is.	9.0
May 22, 1960	Chile	9.9
Oct 13, 1963	Iturup	9.0 (??)
Mar 28, 1964	Alaska	9.6

ANNOUNCEMENTS



WORLD MAP OF HAZARDS

The figure above is a portion of a recently released World Map of Natural Hazards, which illustrates the world-wide distribution of exposure to extreme events in nature. The map and accompanying explanatory publication indicate vulnerability to earthquake, seismic sea waves, volcanic eruptions, tropical cyclones, tornadoes, thunderstorms, fog and iceberg drift.

Ordering information is available from Munchener Ruckversicherungs-Gesellschaft, Postfach 40 13 20, D-8000 Munchen 40, Germany.

New Regional Seismic Map Series Started

National Geophysical and Solar-Terrestrial Data Center (NGSDC) and United States Geological Survey (USGS) have agreed to a cooperative project to produce a series of regional seismicity maps in color. The first map will be for the mid-America region (5° to 35° north latitude) and is scheduled to be available this summer. The USGS will provide scientific guidance and pay printing costs. NGSDC will supply the data base and plotting expertise.

For further information, please write to: National Geophysical and Solar-Terrestrial Data Center, D6, Environmental Data and Information Services, NOAA, Boulder, Colorado 80303.

Volcanoes of the World Map

A new six color 3' x 5' map of active volcanoes of the world has just been printed. The map shows the location, recency and frequency of eruptions for all volcanoes over the last 12,000 years. It is based on data supplied by the Smithsonian Institution and was published by World Data Center-A (Volcanology) operated by National Geophysical and Solar-Terrestrial Data Center (NGSDC) for the International Association of Volcanology as a contribution to the International Geodynamics Program.

For further information, please write to: World Data Center-A (Volcanology), National Geophysical and Solar-Terrestrial Data Center, Environmental Data and Information Services, NOAA, Boulder, Colorado 80303.

Local Response to Earthquake Predictions

The City of Los Angeles has recently published a report of the Mayor's Task Force on Earthquake Prediction. The study is a comprehensive examination of the necessary and appropriate response of local government to scientific earthquake predictions. It deals with such wide-ranging topics as social-psychological impacts of the prediction upon the population, economic stability of the area, safety of buildings, public information problems, emergency preparedness and legal aspects of the prediction.

The report proposes strategies to enable the city to respond appropriately whatever the characteristics of the prediction, taking into consideration such factors as the intensity of the expected earthquake, the date of its projected occurrence, and the credibility of the source of the prediction. Specific plans are presented for coping with predictions of low probabilities or those from non-scientific sources.

Information about the report may be obtained from Rachel Gulliver Dunne, Chairman, Mayor's Task Force on Earthquake Prediction, City of Los Angeles, City Hall, Los Angeles, CA 90012, (213) 485-3311.

Hazards Bibliography Available

The Selected, Partially Annotated Bibliography of Regent (1977-1978) Natural Hazards Publications is now available from the Natural Hazards Research and Applications Information Center, IBS #6, Campus Box 482, University of Colorado, Boulder, CO 80309. Compiled by David Morton, the bibliography contains approximately 200 citations of articles, reports, and studies that pertain to the societal aspects of natural hazards and disasters. The 90-page bibliography is indexed both by author and by subject. Price: $3.00.

International Working Group on Disasters

An International Working Group for the Study of Social and Behavioral Aspects of Disasters was formed during an international meeting of sociologists at Uppsala, Sweden in August 1978. The Group, which consists of researchers from twelve countries, is seeking to establish better communication between persons around the world who are concerned with the sociological aspects of disasters. It is hoped that a more formal association will be created in the future.

The Group will communicate information about research, publications and meetings initially through Unscheduled Events, the quarterly newsletter of the Disaster Research Center at Ohio State University. Persons who wish to receive the newsletter or information about membership in the Group should contact the U.S. liaison, E.L. Quarantelli, The Disaster Research Center, Derby Hall, 154 No. Oval Mall, Ohio State University, Columbus, OH 43210, (614) 422-5916.

The Earthquake Engineering Research Institute Sponsors Conference on Earthquake Engineering, August 22-24, 1979 at Stanford University

Technical, social and political aspects of earthquake engineering will be featured in an effort to disseminate information about earthquakes, stimulate cooperation between other disciplines in coping with earthquakes, and to spread new research and design knowledge.

Both state-of-the-art and specialized research papers are invited. The deadline for submission of abstracts for consideration was January 8, 1979. There will be a published volume of proceedings.

For further information, contact Program Committee, Earthquake Engineering Conference, Department of Civil Engineering, Stanford University, Stanford, California 94305.

"Environmental Forces on Engineering Structures" to be held at Imperial College, London, England; 2-6 July 1979

A conference dealing with the above subject will focus on the behaviour of structures under stress from earthquake, wind, or wave forces. The design requirements for resistance to these environmental factors will be the topic of interdisciplinary discussion. The conference will be sponsored by the Engineering Structures Journal and the Applied Mathematical Modelling Journal.

For information, contact: Dr. C. Brebbia, Southampton University, Southampton 509 5 NH, England.

XIV Pacific Science Congress to be held in Khabarovsk, USSR; 20 August - 5 September 1979

The broad subject of this Congress is "Natural Resources of the Pacific Ocean for the Benefit of Humanity." The symposium on Physical Oceanology includes tsunamis. Further information may be obtained from:

Organizing Committee, XIV Pacific Science Congress, The Academy of Sciences of the USSR, 12 Zhdanov Street, Room 90, Moscow, 103045 USSR.

Symposium on Petroleum Potential in Island Arcs, Small Ocean Basins, Submerged Margins, and Related Areas to be held in Suva or Nadi, Fiji; 18-21 September 1979

This symposium is being held by the Committee for the Coordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas (CCOP/SOPAC), an arm of the Economic and Social Commission for Asia and the Pacific, UNDP.

Both invited and contributed papers will be included on the topics of: Geology and Tectonics; Hydrocarbon Generation; Reservoir Types; Geophysical Techniques in Exploration; State of the Art in Deep Water Offshore Technology; and Case Histories. Selected papers will be published in the Technical Bulletin series of CCOP/SOPAC.

For further information, write to: CCOP/SOPAC Technical Secretariat, c/o Mineral Resources Department, Private Mail Bag, G.P.O., Suva, Fiji.

IUGG Tsunami Meeting to be held in Canberra, Australia; 6-7 December 1979

The Tsunami Committee of the International Union of Geodesy and Geophysics (IUGG) will hold its biannual meetings in conjunction with the 23rd General Assembly in Canberra, Australia on 6-7 December 1979.

International Conference on Engineering for Protection from Natural Disasters to be held in Bangkok, Thailand; 7-10 January 1980

This conference is sponsored by the Asian Institute of Technology, the Canadian International Development Agency and the Southeast Asian Society of Soil Engineering.

For information, write to: Division of Geotechnical and Transportation Engineering, Asian Institute of Technology, P.O. Box 2754, Bangkok, Thailand.

Fifth Gondwana Symposium to be held in Wellington, New Zealand; 11-16 February 1980

This symposium is sponsored by the International Union of Geological Sciences (IUES).

For further information write to: Dr. R.E. Wass, Department of Geology, University of Sydney, Australia 2600.

ABSTRACTS AND RESUMES

A Numerical Experiment for the Tsunami Accompanying the Izu-Oshima-kinkai Earthquake of 1978

Isamu Aida
Earthquake Research Institute
University of Tokyo
Tokyo, Japan

Bulletin Earthquake Research Institute, Vol 53, pp 863-873, 1978
(In Japanese with English abstract)

Abstract

On the basis of the vertical deformation of the ocean bottom deduced from a seismologically determined fault model, a resulting tsunami is computed numerically, in which the linear shallow water equations are used. To make the computed tsunami signatures at selected locations consistent with actually observed records, the location and length of the seismic fault are varied, while the other parameters, such as the dip angle, the strike direction, the fault width and the seismic moment, are fixed. Over-all features of the observed tsunami at selected stations except at Okada are fairly well explained by the above mentioned adjustment of the fault model. It is noticed that the tsunami record at Okada can be reasonably well reproduced only when the subsidence of above 3cm in the sea bottom with radius 4km northwest of Oshima Island is assumed. However, the existence of this subsidence seems to be inconsistent with the aftershock distribution and also with various fault models proposed so far.

Modification of the Response Characteristics of Bay Water due to an Incoming Tsunami of Very Large Amplitude

Isamu Aida
Earthquake Research Institute
University of Tokyo
Tokyo, Japan

Bulletin Earthquake Research Institute, Vol 53, pp 1151-1165, 1978
(In Japanese with English abstract)

Abstract

The dependence of bay water oscillations on the amplitude of an incoming tsunami is investigated by means of numerical and hydraulic experiments. A model bay of rectangular shape is considered, in which nearly flat ground lies to the landward of the bay head. Numerical experiments are carried out on the basis of nonlinear shallow water equations including quadratic friction. The computational scheme is programed to be practicable for the flooding of water on land. Hydraulic experiments are carried out in a wave tank 10m long, 40 cm deep and 40 cm wide, in which the small bay

model is put on the one end. The sinusoidal waves are generated at the opposite end.

The following common results are obtained in both kinds of experiments: the damping of bay water oscillations in the small amplitude range ($\eta_m/\bar{h}<0.1$ where η_m is the resonance amplitude and $\bar{h}$ the mean water depth) depends mainly on the wave energy dissipation through a bay mouth. With the increase of the incoming wave amplitude, the contribution of bottom friction becomes large. In $\eta_m/\bar{h}>0.3$, the nonlinear distortion of waves due to the shallowness of the water depth enhances the frictional damping significantly and in the cases of $\eta_m/\bar{h}\fallingdotseq 0.7$, the amplification factor of bay oscillations decreases to 80% of the linear case. Furthermore, if the flooding of water on land is allowed, the amplification factor becomes as small as 70% of the linear estimation for $\eta_m/\bar{h}\fallingdotseq 0.5$.

In Ofunato and Onagawa bays, located in northeastern Honshu, Japan, the amplification of inundation heights in the case of the Chilean Tsunami of 1960 are 0.5∿0.6 of the values estimated on the basis of seiches measured in ordinary days. If we assume this reduction of the amplification to be the effect of the friction, the friction factor is estimated to be about 0.007, which is considerably larger than the value for the tide.

Numerical Experiments for the Tsunami Accompanying the Miyagiken-oki Earthquake of 1978

Isamu Aida
Earthquake Research Institute
University of Tokyo
Tokyo, Japan

Bulletin Earthquake Research Institute, Vol 53, pp 1167-1175, 1978
(In Japanese with English abstract)

Numerical experiments for this tsunami are carried out on the basis of the seismic fault model deduced from seismological data. By adjusting some parameters of the seismic fault such as the length, the width, the location and the slip displacement, the optimum model is sought so that the computed tsunami signatures are consistent with the records of actual observation. The optimum model thus obtained is only slightly different from the seismic fault model proposed by SENO et al. (1978). The result gives the location of the southeastern corner of the fault as 142.32°E, 38.16°N, the length in the strike direction as 26 km, the width as 65 km, the slip dislocation as 2.0 m (dip-slip 1.97 m, strike-slip 0.48 m). The depth of the upper edge of the fault (25 km) and the dip angle (20°) are the same as the seismic fault model. The seismic moment is estimated to be 2.4×10^{27} dyn·cm which is a little smaller than the value (2.9×10^{27} dyn·cm) obtained seismologically by SENO et al. The tsunami energy is 8×10^{18} ergs which is about 1/5 of the value previously estimated for the ordinary tsunami with the same seismic moment.

The aftershock distribution of this earthquake might suggest the existence of an additional fault with a high dip angle at the eastern end of

the main-fault with a low dip-angle. To check this possibility, several double fault models with different displacements of the sub-fault are examined. The result shows that the slip displacement on this sub-fault has to be less than 0.1 m, which corresponds to only 1/17 of the slip displacement of the main-fault. The existence of the sub-fault, therefore, seems to be irrelevant to explain the behavior of this tsunami.

The Tsunami Generated off Miyagi Prefecture in 1978 and Tsunami Activity in the Region

Tokutaro Hatori
Earthquake Research Institute
University of Tokyo
Tokyo, Japan

Bulletin Earthquake Research Institute, Vol 53, pp 1177-1189, 1978
(In Japanese with English abstract)

Based on tide gauge records, the source area of the 1978 Miyagi-oki tsunami (June 12, 1978) and past tsunamis which were generated in the vicinity of Miyagi Prefecture in the Northeast Japan since 1897 are investigated. At Miyagi-Enoshima, the initial disturbance of the present tsunami began with an upward motion simultaneously with the earthquake occurrence. The source area estimated by means of an inverse refraction diagram is 5.5×10^3 km^2, extending 100 km parallel to the Miyagi coast. The source area of the tsunami which raised the sea-bottom covers the aftershock areas of the two earthquakes of Feb. 20, and June 12, 1978. Judging from the attenuation of the tsunami height with distance, the magnitude (Imamura-Iida scale) of the present tsunami is $m = 0.5$. This rank is relatively low for an earthquake having magnitude $M = 7.4$.

The distribution patterns of seismic intensity and tsunami height for the Miyagi-oki tsunami of Feb. 20, 1897 are similar to those of the present tsunami, suggesting the same source location. According to the space-time diagram of tsunami activity off Miyagi Prefecture, the region from the 1,000 m depth line to near the trench, the east side of the present tsunami may be a region of relatively high tsunami risk.

Field Investigation of the Tokai Tsunamis in 1707 and 1854 along the Mie Coast, East Kii Peninsula

Tokutaro Hatori
Earthquake Research Institute
University of Tokyo
Tokyo, Japan

Bulletin Earthquake Research Institute, Vol 53, pp 1191-1225, 1978
(In Japanese with English abstract)

Abstract

There are many old monuments of the Tokai tsunamis of Hoei (Oct. 28, 1707) and Ansei (Dec. 23, 1854) along the Mie coast, the Pacific coasts in Central Japan. Most of these monuments were built just after the earthquakes to pray for the repose of the tsunami victims and some indicate the inundation levels of the tsunamis. In the present paper, the monuments scattered along the Mie coast are illustrated. Based on descriptions on the monuments, adding new data collected from the present field investigation, inundation heights of the 1707 Hoei and 1854 Ansei tsunamis along the Mie coast are examined in comparison with those of the 1944 Tonankai tsunami.

Inundation heights of the 1854 Ansei tsunami along the Kumano-nada coast, the east of the Kii Peninsula, are 5 to 6 meters with the localized run-up maximum of 8 to 10 meters. The estimated heights of the 1707 Hoei tsunami are almost the same as those of the 1854 Ansei tsunami. The inundation heights of the two historical tsunamis are 1.2 times as large as those of the 1944 Tonankai tsunami. Along the Kumano-nada coast, and in Owase and Gokasho bays, etc., the patterns of height distribution of the two historical tsunamis are similar to those of the 1944 tsunami. It is suggested that the three tsunamis have the same long period.

On the contrary, along the Ise and Shima coasts facing Ise Bay, north-eastern Mie Prefecture, the inundation heights of the two historical tsunamis are average 2.4 times as large as those of the 1944 Tonankai tsunami. Along these districts, the wave heights of the 1944 tsunami were only 2 to 3 meters. It suggests that the source areas of the 1707 and 1854 tsunamis extended further to the north-east along the Nankai trough than that of the 1944 tsunami.

Reliability of a Tsunami Source Model Derived from Fault Parameters

Isamu Aida
Earthquake Research Institute
University of Tokyo
Tokyo, Japan

J. Phys. Earth, Vol 26, pp 57-73, 1978

Abstract

Numerical experiments of tsunami generation and propagation are carried out for five earthquakes which occurred off the Pacific coast of the Tohoku and Hokkaido districts. The tsunami sources used in the experiments are the vertical displacement field of the sea bottom derived from the seismic fault model for each earthquake. Water surface disturbances are computed by a finite difference hydrodynamical method with finer grids in shallower water. The comparison of the computed tsunami behavior with available tsunami records along the coast shows that the distribution of observed tsunami heights can be explained in the first approximation by seismic fault models while the observed heights are 1.2 to 1.6 times

larger than the computed heights. An example of a fault model inferred from seismic data (June 12, 1968) which is not suitable for a tsunami source is presented.

Tsunamis -- The Propagation of Long Waves onto a Shelf

Derek Garard Goring
W. M. Keck Laboratory of Hydraulics and Water Resources
Division of Engineering and Applied Science
California Institute of Technology
Pasadena, California

Report No. KH-R-38, November 1978

Abstract

The various aspects of the propagation of long waves onto a shelf (i.e., reflection, transmission and propagation on the shelf) are examined experimentally and theoretically. The results are applied to tsunamis propagating onto the continental shelf.

A numerical method of solving the one-dimensional Boussinesq equations for constant depth using finite element techniques is presented. The method is extended to the case of an arbitrary variation in depth (i.e., gradually to abruptly varying depth) in the direction of wave propagation. The scheme is applied to the propagation of solitary waves over a slope onto a shelf and is confirmed by experiments.

A theory is developed for the generation in the laboratory of long waves of permanent form, i.e., solitary and cnoidal waves. The theory, which incorporates the nonlinear aspects of the problem, applies to wave generators which consist of a vertical plate which moves horizontally. Experiments have been conducted and the results agree well with the generation theory. In addition, these results are used to compare the shape, celerity and damping characteristics of the generated waves with the long wave theories.

The solution of the linear nondispersive theory for harmonic waves of a single frequency propagating over a slope onto a shelf is extended to the case of solitary waves. Comparisons of this analysis with the nonlinear dispersive theory and experiments are presented.

Comparisons of experiments with solitary and cnoidal waves with the predictions of the various theories indicate that, apart from propagation, the reflection of waves from a change in depth is a linear process except in extreme cases. However, the transmission and the propagation of both the transmitted and the reflected waves in general are nonlinear processes. Exceptions are waves with heights which are very small compared to the depth. For these waves, the entire process of propagation onto a shelf in the vicinity of the shelf is linear. Tsunamis propagating from the deep ocean onto the continental shelf probably fall in this class.

Tsunami Warning Service and Its System in Japan

Hideo Watanabe
Seismological Division
Japanese Meteorological Agency

Reprint of Japanese Meteorological Agency

Abstract

The tsunami warning service in Japan has been reinforced and improved since the service has started on April 1, 1952. The service consists of three parts: 1) tsunami forecast system, 2) dissemination system to transmit messages to coast, 3) terminal system to evacuate the people rapidly on receiving warning. The first part is operated exclusively by the Japan Meteorological Agency (JMA).

The system for tsunami warning in the JMA is composed of seismic monitoring stations, tidal monitoring stations and analysis centers. Telemetered seismic observation system has been developed in order to locate earthquake in and near Japan as quickly as possible for the purpose of tsunami warning.

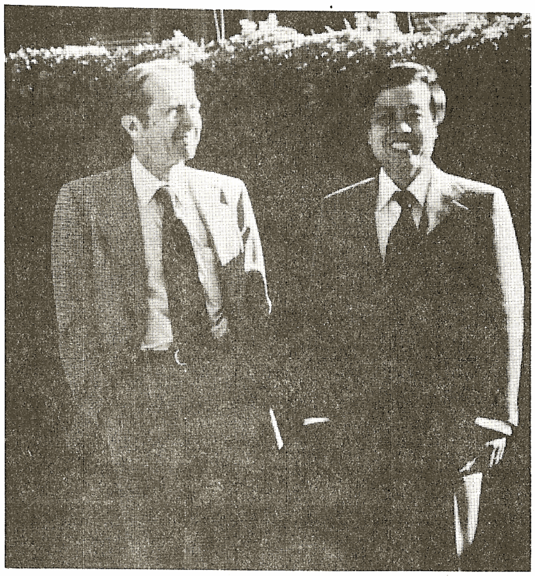
The functions of the analysis center are as follows: 1) location of epicenter, 2) determination of grade magnitude of tsunami and 3) determination of warning message.

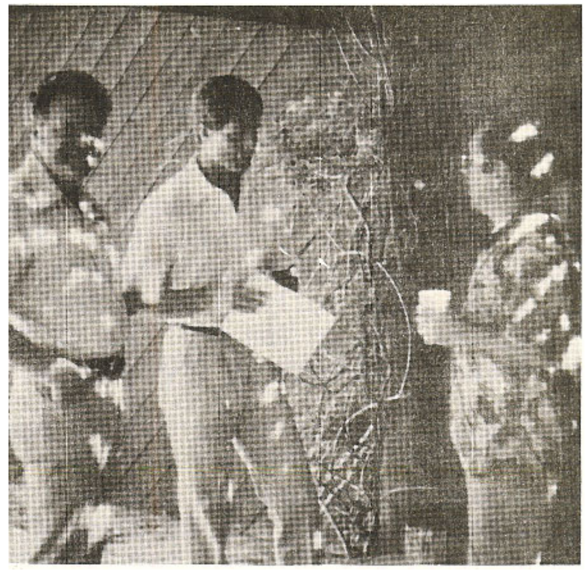
The tsunami warning message prepared at the center is sent to the dissemination centers. The offices of villages, towns or cities along the coast which have received by telephone, telegraph, radio or television etc., should inform the people of it by fire bells or sirens.

PACIFIC TSUNAMI WARNING CENTER

Seismic Summary (December 24, 1978 to Press Time)

Event No.		Event	Location	Action Taken
1979-1	(PTWC)	Jan 26 1004 (UT) 6.8	Nr. Acapulco, Mexico 17.1 N 99.9 W	Press Release
1979-2	(PTWC)	Feb 16 1008 (UT) 6.6	Arequipa, Mexico 16.44 S 72.56 W	Press Release
1979-3	(PTWC)	Feb 28 2127 (UT) 6.8	SE Alaska 60.6 N 141.7 W	Press Release
1979-4	(PTWC)	Mar 14 1107 (UT) 7.1	Mexico 17.82 N 101.26 W	Press Release
1979-5	(PTWC)	Apr 9 0142 (UT) 6.9	Talaud Is. Region 3.7 S 126.9 E	Press Release
1979-6	(PTWC)	Apr 14 1000 (UT) 6.7	Easter Island 35.98 N 102.42 W	Press Release
1979-7	(PTWC)	May 1 1303 (UT) 6.8	Near Loyalty Islands 19.7 N 170.8 E	Press Release





Professor George Carrier of Harvard University and Dr. Li-San Huang of Tetra Tech and Chairman of the Tsunami Workshop.

Dr. William M. Adams of the University of Hawaii (left), John Nelson of the World Data Center-A (center), and Dr. Dennis Moore (right), Director of JIMAR of the University of Hawaii, during a break of the Tsunami Workshop,at Coto de Caza.

Participants of the Tsunami Workshop at Coto de Caza exiting the conference room during a short recess.

SPECIAL BULLETIN

Tsunamis in Indonesia *(By George Pararas-Carayannis)*

Preliminary reports from Indonesia state that on July 18 and approximately at 1:00 AM (local time), 7-9 meter tsunami waves believed triggered by a volcanic eruption smashed into the remote island of Lomblen at approximately 140 kilometers an hour, sweeping away hundreds of people in four villages. Initial reports stated that 171 people were killed and as many as 700 were missing. Subsequent reports indicated that 539 people were killed, but the death toll may be higher. The waves crested at about 9 meters, crashing down on the villages as most of the inhabitants slept. The waves traveled as much as 1500 meters inland.

The tsunami waves were believed to have been caused by the collapse of the island's 1,000 meter Gunung Werung volcano into the Flores Sea. The volcano has now been reduced to one half its original size. According to these preliminary reports, the collapse of the volcano was followed by several eruptions, but this has not been confirmed so far by ITIC inquiries. ITIC is in the process of investigating this event and has been in contact with the National Institute of Oceanology in Jakarta and other scientific organizations. Indonesian survey teams have been dispatched to the area, but because of the remoteness of the region and difficulty of communications, conclusive reports are not expected for a while. It is not knownat this time whether the tsunami waves were triggered by the collapse of the volcanic summit as it was the case with the Krakatoa eruption of 1883, or whether the waves resulted from a massive landslide into the Flores Sea. Investigation of seismic records at the Pacific Tsunami Warning Center failed to determine the occurrence of a small or large earthquake in the area during that time which could have triggered a landslide.

According to military reports "tons of rocks and earth rolled down the mountain, whose top fell into the sea, creating huge tidal waves that swept ashore and killed the entire population of four villages in a few seconds," Also, according to informal reports, several wide cracks had been observed on the sides of the Gunung Werung volcano recently, but inhabitants refused to listen to warnings by authorities to evacuate the area.

The waves that swept Lomblen island are reminiscent of the Krakatoa disaster of August 26, 1883, nearly 100 years ago. The explosion and collapse of the Krakatoa volcano created tsunami waves as high as 35 meters which destroyed all the towns and villages on Sunda Strait, killing 36,000 people on Java and Sumatra. It has been reported that the remains of Krakatoa have since July 20 been spewing out black fumes and red-hot lava.

ITIC will continue to investigate the recent tsunami in Indonesia and will prepare a final report when the surveys are completed.

REPORT ON THE USE OF SATELLITES

IN THE TSUNAMI WARNING SYSTEM

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International Tsunami Information Center

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This report was prepared at the request of the International Co-ordination Group for the Tsunami Warning System in the Pacific (ITSU).

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The section of the report, "Status of Development in Japan", was contributed by Dr. H. Watanabe, National Contact for ITSU, and Head, Seismological Division, Japan Meteorological Agency.

Dr. E. Bernard, Director, Pacific Tsunami Warning Center (PTWC), and Dr. G. Pararas-Carayannis, Director, International Tsunami Information Center (ITIC), have reviewed the report and its relation to the Tsunami Warning System for the Pacific, and also in relation to their report on the system of gauges needed to provide one-hour verification of the existence of a tsunami.

Preamble

The summary of proceedings of the sixth meeting of the International Co-ordination Group for the Tsunami Warning System in the Pacific, held in Manila in February 1978, contains the following paragraphs under Item 9:

Proposals for further technical improvements of the Tsuanmi Warning System in the Pacific (TWS)

The Director of ITIC summarized the progress made to date and presented plans for further technical improvements for the Tsunami Warning System. The Chairman established an ad hoc group on technical improvements which developed the following action plan which was adopted by the Group:

The Group requests Canada and the U.S.A. to investigate the use of satellites in the TWS and to prepare a report for publication in the ITIC newsletter by 1 January 1979. The USSR and Japan are requested to provide information on their satellite programmes by 1 June 1978 for inclusion in this report.

The Group requests each Member State to review the communication facilities between its TWS gauges and the Pacific Tsunami Warning Center (PTWC) and submit a report to ITIC recommending the most expedient means of communication. This report should be submitted to ITIC by 1 June 1978.

The ITIC will review these recommendations and suggest improvements in the TWS communication plan. Implementation of these recommended improvements will be the responsibility of the Member States.

The Group is of the opinion that the goal of the TWS should be to verify the existence of a tsunami within one hour after the time of generation. As a first step, ITIC and PTWC will prepare a report defining the system of TWS gauges needed to achieve the goal. The recommended network of gauges, based on historical data and communication links, will be published in the ITIC newsletter by September 1978. Member States are requested to consider establishment of the recommended gauges as appropriate and to report to ITSU-VII on their progress.

The Group requests each Member State to provide ITIC with a description of existing gauging equipment utilized at each tsunami gauge site, as well as any planned improvements. This information should be submitted by 1 June 1978.

Preparatory Work and Policy

In order to fulfill the requirements set forth in paragraph 2 of ITSU Item 9, an ad hoc working group was formed in April 1978, and held a series and meetings in Canada at Sidney, Ottawa, and Burlington. Limitations of the study were defined, in particular that it would be concerned with existing technology for supplying data from tide and seismic stations via satellite to PTWC. Three possible modes of activation for the system were considered, interrogation, fixed time transmissions, or event-induced broadcast. Interrogation from PTWC was selected as most practical at this time. The study was limited also to determining an economical system for collection of that data needed for tsunami warning, and not to meeting other requirements for the data. Participants investigated and reported on the various technical aspects. A draft report was compiled and circulated for comment and correction, and the responses have been considered in compiling this final report.

This report sets forth instrumentation available now, and an estimate of costs entailed to have an automated tidal station placed in service for TWS. Combined with the report being prepared by ITIC and PTWC defining the stations required to verify the existence of a tsunami within one hour of its generation (paragraph 5 of ITSU Item 9), the cost of automating the data collection for the Tsunami Warning System can be estimated.

Detection of tsunami waves in deep ocean by altimetry measurements from orbiting satellites was recognized as a possibility, but not practicable for TWS without considerable research and testing.

Possible use of satellites for the dissemination of warnings is not considered in this report.

Satellites

Characteristics of various orbiting and geostationary satellites were reviewed, and their possible use in TWS data transmission was considered. It was recognized that the Geostationary Operating Environmental Satellite (GOES) system had been designed in part to meet data transmission requirements of TWS. For automating and speeding the transmission of seismic and water level data to PTWC after an earthquake the GOES system is presently most suitable.

Two GOES satellites operated by NOAA are available for service in TWS. They are located over the equator at 75° and 135°W longitude. Coverage, as shown on Figure 1, includes all of North and South America and most of the Pacific. Data from individual platforms is transmitted in 8-bit ASCII, at a rate of 100 bits per second over one of 80 channels currently available. Each GOES has one interrogate channel which is used for polling platforms when data are desired. The interrogate channels are 469 MHZ. Platforms transmit at frequencies of 401.7 to 402.1 MHZ.

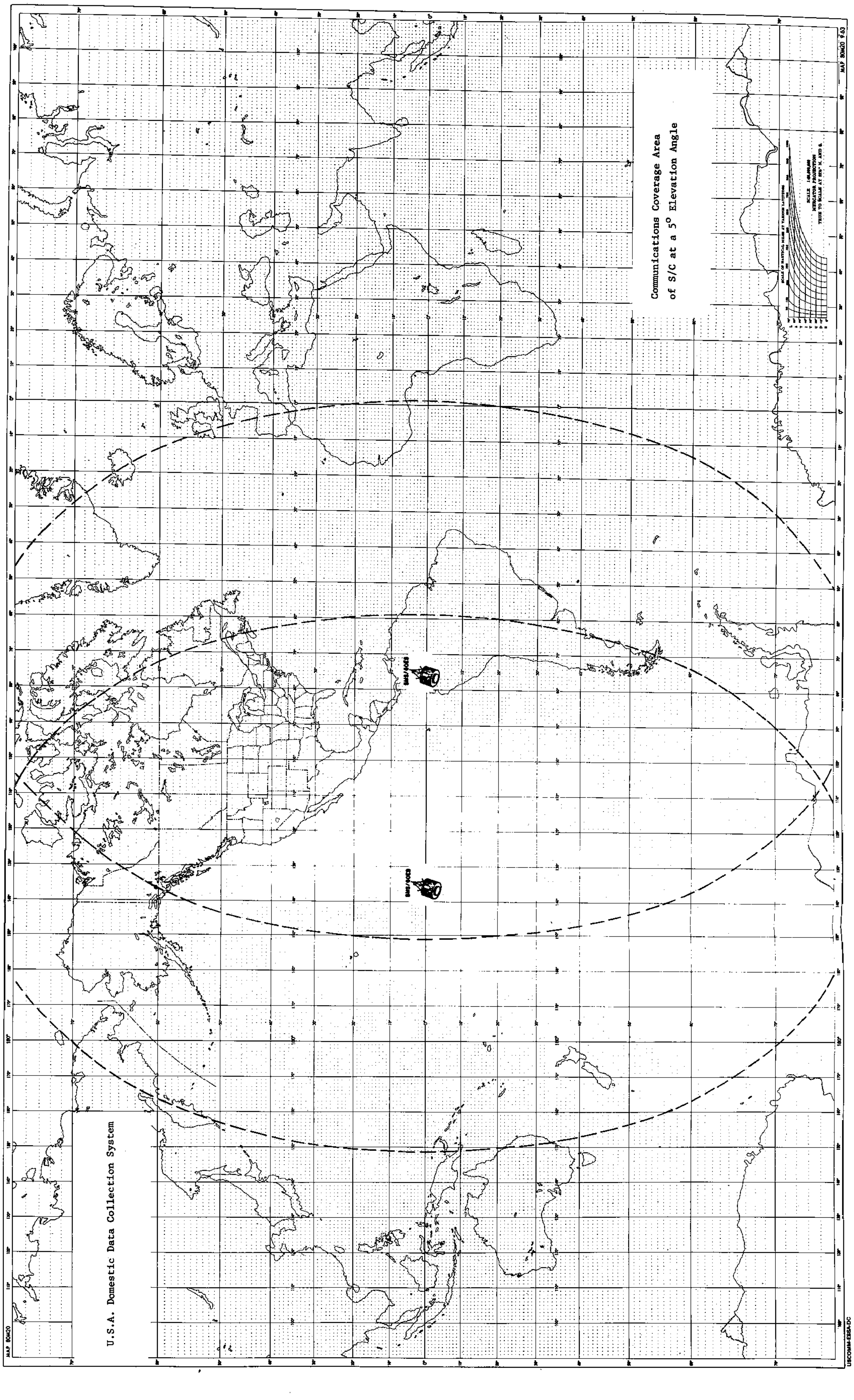

Figure 1. GOES Satellite Coverage from 75° West Longitude

Organizations desiring to use the GOES satellite for data collection may direct queries to the Chief, Satellite Services Division, National Environmental Satellite Service, NOAA, Washington, D.C. 20233.

Tide and Tsunami Platform

The basic requirements for a tsunami detection station transmitting via satellite are the following:

1. Water Level Sensor:- Standard float or pressure actuated tide gauges can be adapted to automated data transmission. Inexpensive pressure transducers may be the most economical for tsunami detection. If the gauge is required for precision water level measurements in addition to tsunami detection, a more expensive pressure sensor will be required. For example, a crystal pressure sensor may cost about $2000, and add about 25% to the cost of the system.

2. Interrogable Radio:- GOES transceivers are commercially manufactured and available.

3. Interface:- An interface and data storage unit is needed which will accept data from one or several sensors and transfer them to the GOES transmitter as required. The interface will probably employ a low-power microprocessor. Barometric compensation may be introduced by one sensor to provide atmospheric compensation, if water levels are being measured by crystal pressure sensor.

4. Power Source:- Many sites for tsunami sensors will have normal community electrical power sources available. A supplementary source, for example rechargeable batteries, is recommended to ensure no disruption of service. For remote sites lacking a community power source, solar panels and rechargeable or disposable batteries are recommended. It is clearly important that the sensor, transceiver, and interface have very low power consumption.

5. Site Requirement:- The antenna must be located to have clear line of sight to the satellite. A location near the sensor is desirable, to minimize risk of accidental damage or vandalism to the connecting line, to improve reliability, and to reduce costs.

GOES Seismic Platforms

These platforms will make use of data from existing observatories. A short-period seismometer will be fed to a "P-picker", a microprocessor-based event detector which will detect, time, and store the onset of primary seismic waves. These primary wave arrival times will be stored for transmission to the PTWC when required. Consequently, the GOES package for seismic platforms will include a GOES transceiver, microprocessor with associated storage, and interface electronics, antenna, and necessary power source and wiring. A diagram of the tsunami satellite systems is shown in Figure 2.

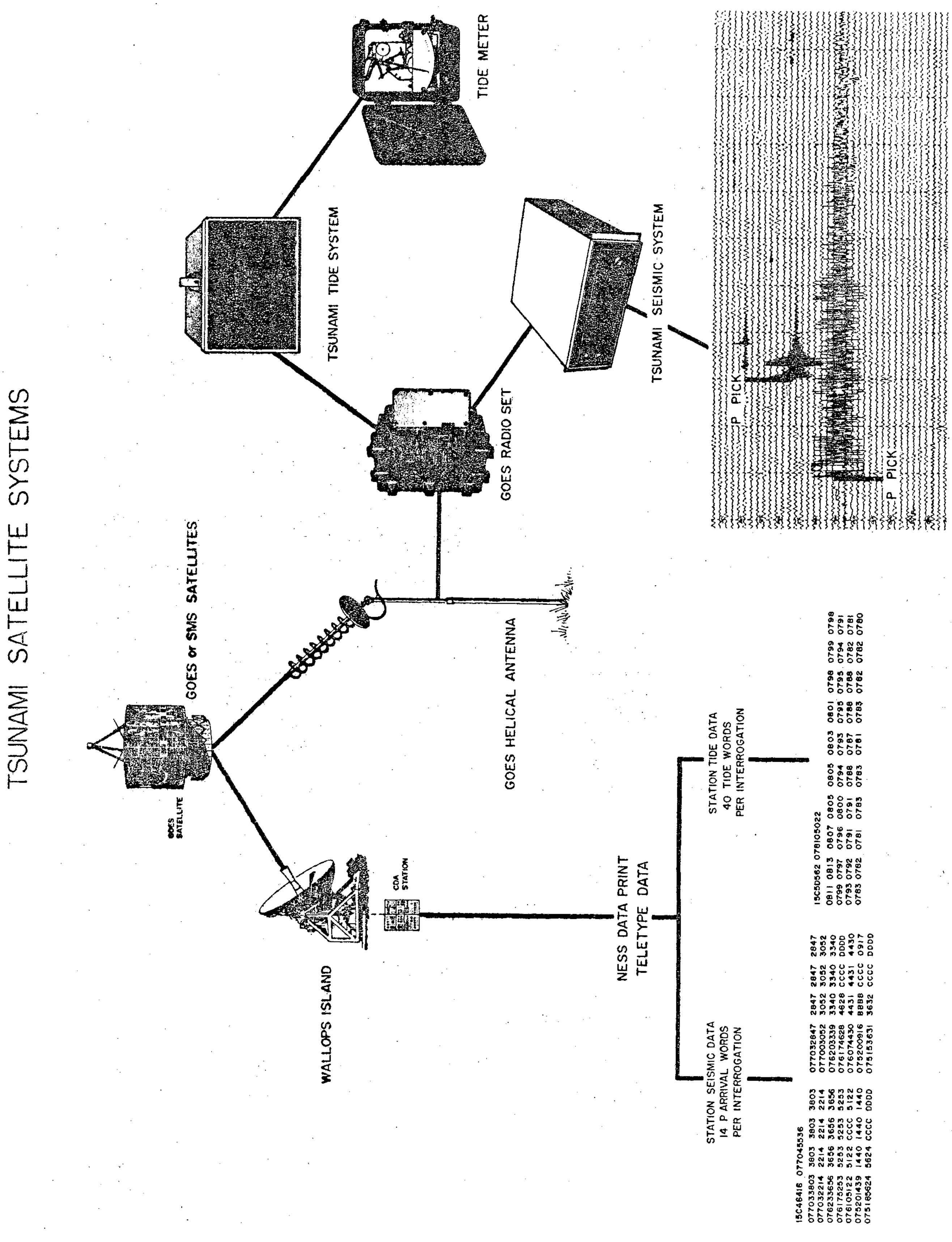

Figure 2. Diagram of Tsunami Satellite Systems

Status of Development in United States

The U.S.A. has, at the time of writing, one tide platform and two seismic platforms operating. The following is a description of the equipment and operating procedure for the tidal station:

The tidal platform operating at this time obtains its data from a Bristol transmitter driven by a float-activated gauge at La Jolla, California. A set of data from the platform is transmitted automatically to PTWC via satellite every 6 hours, to ensure proper functioning of the system. The station can also be interrogated by PTWC. A second platform being prepared for service will obtain its data from a vibrotron pressure transducer located off the shore of Wake Island in approximately 300 m. of water. Power is available at each site.

When data are required by PTWC, the NESS ground station at the World Weather Building is requested to interrogate the platform. Presently, the request comes by telephone at which time PTWC specifies the duration of 15-minute interrogations (i.e. "interrogate platform X for three hours at 15-minute intervals beginning at 2100Z"). NESS will interrogate the platform according to the instructions. Forty water level readings taken at thirty second intervals up to the time of interrogation are then transmitted to NESS by the platform. PTWC then connects its computer terminal to the NESS computer via telephone and these data are transmitted to PTWC within thirty seconds of connect. As long as the terminal remains connected to the NESS computer, data are transmitted to PTWC at the end of each interrogation automatically.

Status of Development in Canada

Canada expects to have its first tsunami prototype operational at Bamfield, on the west coast of Vancouver Island, during 1979. Equipment is already installed, and being tested. A Paroscientific crystal pressure transducer will supply the water level data. The interface is a single board microcomputer developed by the Tidal Instrument Development Group at the Canadian Center for Inland Waters. This type of instrumentation has already been used for acquiring water levels from permanent gauging sites. Transmission to satellite will be made by LaBarge or Magnavox transceiver.

It is expected that the operating procedure for interrogation will be very similar to that presently used in United States. The data in storage on the Bamfield gauge will also be available through a telephone connection. Operator interaction via land line through a modem link can correct the gauge time, change the sampling frequency, and the datum for water level measurements.

Status of Development in Japan

On July 14, 1977, the Geostationary Meteorological Satellite (GMS) was launched by Japan, and the GMS system has been operational since April, 1978.

GMS is stationed at 140°E, 35,800 km above the equator. Japan Meteorological Agency prepared the necessary ground facilities, and is in charge of operating the system including the spacecraft. GMS is used for acquiring cloud information in both visible and infrared wave region, disseminating processed cloud facsimile to users, collecting meteorological data from data collection platforms, and for monitoring solar particles. As for the data collection function of the system, data from DCPs are received by the spacecraft, which relays the data signals to the Command and Data Acquisition Station (CDAS). Then the signals are transmitted to the Data Processing Center (DPC) where they are compiled by a large computer system. Those data are distributed to users via the Global Telecommunication System (GTS). It should be noted that the current system allows data collection only at given times, and that use of only WMO FM codes are allowed. Interrogation of DCPs is carried out on frequencies of approximately 468.9MHZ, and reporting from DCPs to the spacecraft, 402.1MHZ with transmission speed of 100 bits per second. Any DCP operators wishing to use GMS are requested to conclude an agreement with JMA prior to installation and operation of such DCPs.

Detailed information may be available from Japan Meteorological Agency, 1-3-4 Ote-machi, Chiyoda-ku, Tokyo 100, Japan.

Conclusions

It appears from the prototype testing that the satellite transmission of tsunami data from existing tidal stations or from remote sites is practicable within TWS. Given some sort of structure already in existence on which to mount the facilities, a basic tsunami detection station would cost about $15,000 installed. This cost includes a preliminary site investigation which is considered to be imperative in all cases. If no structure exists on which to mount the sensor, the installation costs will increase considerably in most cases.

The time lapse between generating an interrogation message from PTWC to the stations, via satellite, and the receipt of data from the stations appears to be short enough that satellite stations could be used in meeting the ITSU requirement for identification of the existence of a tsunami within one hour from the time of an earthquake.

A number of technical questions need to be addressed, including:

(a) For what period may the GOES satellite be out of service, and what communications options are available at those times?

(b) What supplementary purposes could tsunami detection gauges fulfill? What instrument or communication modifications would be needed to fulfill these needs, and would they increase the cost-effectiveness of the gauges? How would the fulfillment of these needs help to generate the funds needed to acquire and install the network of gauging stations that the ITIC-PTWC study may find necessary to adequately instrument the TWS?

(c) What agencies will operate the tsunami statellite gauges? What maintenance and servicing will be required, and how will this be organized and co-ordinated?